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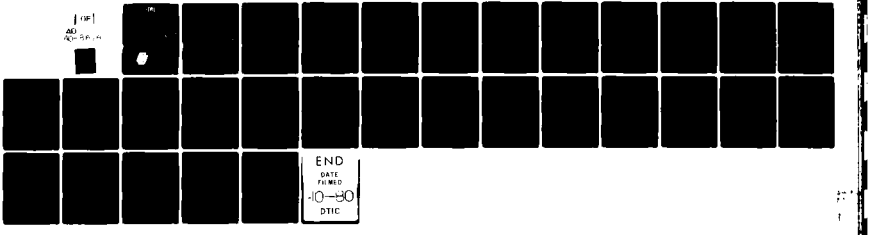

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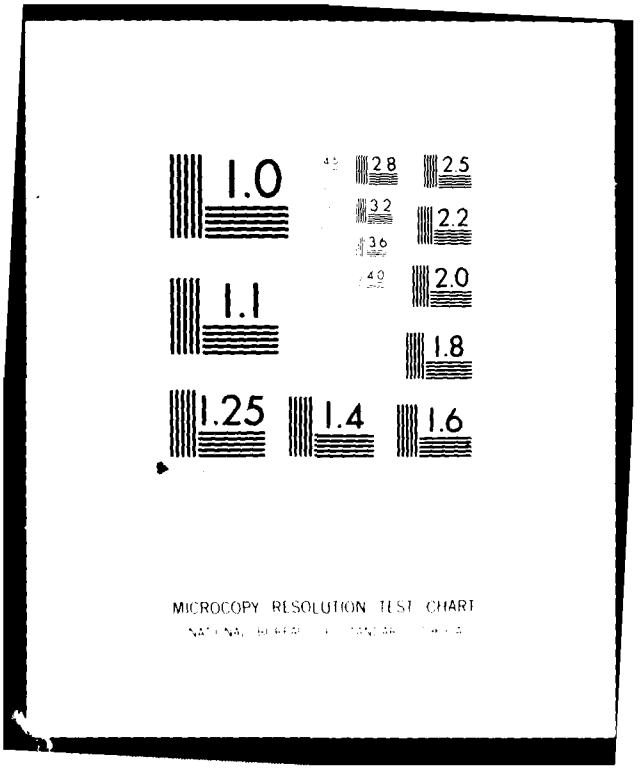
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The Effect of a Previously-Generated Hypothesis on Hypothesis Generation Performance

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An experiment was performed to determine what effects exposure to a previously-generated hypothesis would have on subsequent hypothesis generation.

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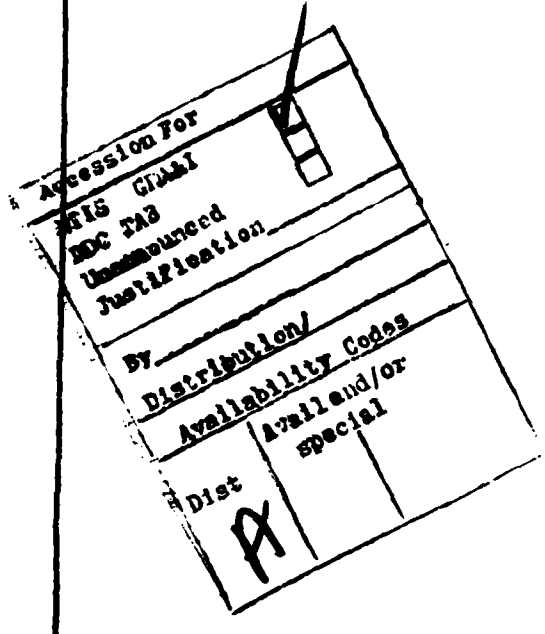
The results showed that hypothesis generation performance is relatively unchanged if the previously-generated hypothesis is consistent with a salient interpretation of the data. However, if the previously-generated hypothesis is consistent with a relatively unusual interpretation of the data, then subjects use both the interpretation that is consistent with the hypothesis and the more commonly used interpretation as cues to retrieve hypotheses. In this case, resulting hypothesis sets included more varied types of hypotheses. Instructions to consider other interpretations of the data also resulted in subjects' generating richer hypothesis sets.



The Effect of a Previously-Generated Hypothesis on Hypothesis Generation Performance

One of the problems often associated with scientific inference and other types of problem solving is attaining a new solution for an old problem. It is often difficult to create unique solutions when one or more solutions are already available. It is sometimes difficult to "build a better mousetrap" because the currently available solution blinds us to other possible solutions.

The present experiment was designed to examine this problem as it occurs during the process of hypothesis generation. Hypothesis generation is a predecision process that involves the retrieval from memory of possible states of the world that might affect the outcomes of acts. These hypotheses are retrieved using part of the available information about the problem as retrieval cues (Gettys and Fisher, 1979). Hypotheses that have been retrieved are rapidly checked for consistency with the remaining data to insure that they are consistent with the data (Fisher, Gettys, Manning, Mehle and Baca, 1979). These hypotheses are then assessed for plausibility (Gettys, Fisher and Mehle, 1978), and implausible hypotheses are discarded at this time. The decision maker uses the resulting set of plausible hypotheses in further decision making. Studies of hypothesis generation have found that humans generate deficient hypothesis sets (Gettys and Fisher, 1979; Mehle, 1980; Manning, Gettys, Nicewander, Fisher and Mehle, 1979); too few hypotheses are retrieved from memory (Gettys and Fisher, 1979; Gettys, Fisher and Mehle, 1978; Fisher, et. al., 1979; Manning, et. al.,

1979), and subjects feel overconfident that hypothesis sets contain a sufficient number of hypotheses (Gettys, Mehle, Baca, Fisher and Manning, 1979; Mehle, Gettys, Manning, Baca and Fisher, 1979; Mehle, 1980).

One aspect of hypothesis generation that has not yet been examined is the ability of the decision maker to generate additional hypotheses when previously-generated hypotheses already sufficiently explain the data. This situation often occurs in the context of scientific investigation. In scientific inference it is difficult to create a new theory that better accounts for the same data that have already been explained by a previous theory. The beauty of Einstein's theory of relativity is that it escaped the dead-end followed by previous theorizing by explaining existing facts in a new way. The ability to look at a problem from a fresh perspective when one solution is already available can be an important component of many other problem-solving situations. The major question to be addressed in this paper is "to what extent do previously-generated hypotheses bias or alter the hypothesis generation process?".

One effect that a previously-generated hypothesis may have on hypothesis generation is to suggest an interpretation for the data. Data in a problem situation may be interpreted in multiple ways. Using different possible interpretation may lead to generating different types of hypotheses. For example, a person might generate hypotheses about the identity of a hypothetical geographical location given the datum "This area is not open to the general public." If one interprets this datum to mean that the area is restricted to protect its contents, then subsequent hypotheses are likely to include uses like "bank vault", "top-secret government laboratory",

etc. However, if one interprets the datum to mean that the area is restricted to protect the public from its contents, then subsequent hypotheses are likely to reflect uses like "sewage treatment plant", "nuclear power plant", etc. It may be that the presence of a previously-generated hypothesis in a problem causes a decision maker to adopt the interpretation that is consistent with the previous hypothesis. Does this process impair the decision maker's ability to consider alternate interpretations of the data and generate hypotheses consistent with those other interpretations?

The term "schema" has been used by cognitive psychologists to describe multiple interpretations of data. There are many definitions of a schema, but those that are most consistent with our usage of the word are "a unifying context into which several pieces of information can be fit", (Thorndyke, 1976) and "a limited set of frameworks within which incoming information will be structured" (Mandler, 1978). Two schemata that might be employed to interprete the datum about the geographical area that is not open to the public are "protection of contents" and "protection of public".

Several experimental findings about schemata are relevant to this discussion. Bransford, McCarrell, Franks and Nitsch, (1977) proposed that subjects' goals involve finding meaning in data, and schemata are employed to assign this meaning. They found that subjects so desire to attain some kind of meaning that they make inferences that are not explicitly provided about relationships between data to gain a greater understanding of the context. Spiro (1977) also found that subjects

make inferences so that data become meaningful. Thus it can be said that schemata organize the data of a problem and add additional meaning to the data.

Information must have meaning for subjects to recall it effectively. Bransford et. al (1977) found that presenting a descriptive title at the time a paragraph was memorized aided later recall as compared to a condition where no title was presented. The hypothesis generation model proposed that subjects use data as cues to retrieve hypotheses. If data are not meaningful to a subject, then they cannot be effective retrieval cues. However, employing a schema to organize data should aid the retrieval process and the schema itself may serve as a retrieval cue. The schema itself may come to represent the data because this interpretation rather than the individual pieces of data are used to retrieve possible hypotheses.

Sometimes alternate schemata must be employed to retrieve all the information associated with a problem context. Anderson and Pichert (1978) showed that subjects who were directed to use a particular perspective (for example, that of a homebuyer) when reading a paragraph about the characteristics of a house later could recall only the attributes consistent with that perspective. However, when they were later directed to change their perspective (to that of a burglar) subjects were capable of recalling additional information that they had not recalled earlier. Subject reports indicated that they were previously unable to recall the "burglar" information until the change in perspective made the additional information "pop into their heads".

These results imply two important points: first, that information is often available, but accessing it may be a problem. The distinction

between availability and accessibility has been made by Tulving and Pearlstone (1966). A datum may be present in memory, but may not be readily accessible. For instance, the knowledge that Franklin Pierce was a former president may be present in many Americans' memories, but few people are likely to have ready access to the knowledge. However, the proper retrieval cue can make formerly inaccessible information more accessible. For example, the retrieval cue "Name the president whose initials were FP" would make the response "Franklin Pierce" more accessible than would the retrieval cue "Who was the 14th President of the United States?". Because the information can be accessed using an effective retrieval cue, we say it is available in memory. Only when it can be retrieved is it accessible.

The second major point is that employing a different schema can aid retrieval. Anderson and Pichert's (1978) manipulation of having subjects change perspective provided an additional retrieval cue, which made new information accessible to their subjects. Similar results are likely to occur in hypothesis generation. Decision makers should have a sufficient data base to insure that hypotheses are available. However, the data may not provide sufficient retrieval cues to make all of those available hypotheses accessible. If schemata act as retrieval cues, then the schema employed by subjects is likely to provide access to only part of the possible hypotheses. Perhaps inducing the decision maker to change schemata could aid hypothesis retrieval by providing new retrieval cues to gain access to other types of hypotheses.

How likely are subjects to change their schema while generating hypotheses? Duncker (1945) showed that displaying the customary use of an object

impaired a subject's ability to utilize the object in an unusual manner in a problem-solving situation. This implies that his subjects found it difficult to change schemata in the middle of a problem, especially if the schema were particularly salient. We expect that hypothesis generators should react similarly.

Throughout this study we will refer to a hypotheses that exist prior to the start of hypothesis generation as "presumed hypothesis". These pre-existing hypotheses are those which the decision maker may have available from past work on the problem. According to our theory, presenting a presumed hypothesis should cause a decision maker to formulate a schema to mediate the relationship between the presumed hypothesis and the data. We will refer to the schema that relates the presumed hypothesis and the data as the presumed schema. The presumed schema need not be the one that the decision makers actually use to retrieve hypotheses. Some other schema may be so salient to decision makers that they utilize both the salient schema and the presumed schema as retrieval cues. However, we believe that the presence of a presumed hypothesis should lead to the adoption of a presumed schema, which should then affect subsequent hypothesis generation.

The present study was performed to answer some of the questions that arise from the previous discussion. Given that subjects are likely to employ schemata to organize data, how will the presence of a presumed hypothesis affect hypothesis generation? We proposed that seeing an exemplar presumed hypothesis would cause subjects to employ a presumed schema to account for the relationship between the hypothesis and the data.

Does utilizing a schema bias a decision maker's ability to generate hypotheses that are consistent with other schemata? Does the presentation of a presumed hypothesis enhance the generation of hypotheses consistent with the presumed schema? We suspect that the presumed schema will be used as a cue to retrieve hypotheses from memory. Subjects who see the presumed hypothesis should generate more hypotheses consistent with the presumed schema than do subjects who do not see the presumed hypothesis.

Is the generation of hypotheses consistent with different schemata suppressed by the presentation of a presumed hypothesis? We propose that fewer hypotheses should be generated that are consistent with schemata other than the presumed schema if a presumed hypothesis is presented.

The next question to be examined is related to subjects' ability to change their schema. Does a manipulation that makes another type of schema more accessible affect the types of hypotheses that subjects generate? We proposed that subjects who can change schemata when prompted to do so should gain access to a new group of hypotheses. These subjects' hypothesis sets should be more varied than lists of subjects who could not change schemata.

Method

Subjects. Subjects were 90 students from the University of Oklahoma who participated in this experiment to fulfill a course requirement. Subjects participated in small groups of up to 10.

Materials. Written test forms consisted of three "Geography" problems, which are displayed in Table 1. The three data described an unknown geographical location, Area X. The subjects' task was to list as many hypotheses as they could that were consistent with all of the data.

Table 1

Geography Problems

Problem 1.

Data: 1. Most People Spend Only A Short Time In Area X.
2. Area X Contains Unusual Smells.
3. Area X Is Only Open During Business Hours.

	More Accessible	Less Accessible
Prime	Dump	Bakery
Schema	Unpleasant Area	Pleasant Area

Problem 2.

Data: 1. The Land Around Area X Is Considered To Be Quite Valuable.
2. Area X Attracts Many Visitors.
3. A Large Land Area Is Desirable For This Use Of Area X.

	More Accessible	Less Accessible
Prime	Race Track	National Park
Schema	Commercial Value	National Heritage

Problem 3.

Data: 1. People Often Spend More Than One Day At A Time In Area X.
2. Large Amounts Of Money Are Spent In Maintaining Area X.
3. Area X Can Accommodate Large Numbers of People.

	More Accessible	Less Accessible
Prime	Resort	Jail
Schema	People Desire To Be There	People Are Forced To Be There

Insert Table 1 about here

The presence of a presumed hypothesis was simulated by using a technique known in the cognitive literature as "priming". A prime is a stimulus that predisposes a subject to respond in a certain way or has an effect on the processing of subsequent stimuli. A presumed hypothesis serves as a prime because it predisposes subjects to adopt the presumed schema. Subsequent hypothesis generation should then be based on the use of that schema as a retrieval cue. Thus subjects seeing a presumed hypothesis should generate more hypotheses consistent with the presumed schema than should subjects who do not see the presumed hypothesis.

The schemata used in this experiment varied in accessibility. The difference in accessibility was determined by examining subjects' responses from previous pilot studies. For each problem, subjects generated more hypotheses consistent with a schema that will be called "more-accessible" (MA). Subjects generated fewer hypotheses that were consistent with a schema that we will call "less-accessible" (LA). The primes were chosen to be representative members of those schemata. The schemata and corresponding primes for each problem are also displayed in Table 1.

The primes were placed before each set of data in the actual problems that subjects' saw to insure that subjects would be more likely to employ the corresponding presumed schema. If the subjects had read the data before they encountered the prime, then they might have employed their own schema instead of the presumed schema.

One third of the test forms contained the LA prime for a problem, one third contained the MA prime and one third contained no prime. A Latin

Square design was used to assign the type of prime to the problems. Thus each test form contained one problem for which the prime was more-accessible, one problem for which the prime was less-accessible, and one problem for which there was no prime.

Design. The major manipulation was the type of prime provided to the subject. Primes either 1) represented a MA schema, 2) represented a LA schema, or 3) were not present.

A second manipulation involved instructional changes. In the "Demonstration" condition, subjects were required to explain why the presumed hypothesis was consistent with the data. This was done to insure that a presumed schema was adopted initially and would influence subsequent hypothesis generation. The problem that contained no prime required no such explanation.

Subjects in the "Fix" condition were requested to provide another hypothesis that was consistent with the data for a different reason than was the prime. It was hoped that this instruction would cause them to generate an alternative to the presumed schema created by the prime. Subjects could then use this alternate schema as an additional retrieval cue to access a different class of hypotheses.

For the problem containing no prime, subjects in the "Fix" condition were instructed to provide their own exemplar hypothesis and explain why it was consistent with the data. This control condition differs from the comparable control condition employed in the "Demonstration" condition. We asked subjects in the "Fix" control condition to generate an exempler hypotheses because differences in performance might occur when subjects actively adopt a schema.

Subjects were tested in small groups. All subjects in a group received the same instructional manipulation. Subjects within a group received different prime and problem combinations.

Procedure. All subjects were told that the purpose of the experiment was to see how they generated hypotheses about a problem when a potential solution had already been provided. Subjects were then given detailed instructions that corresponded to the appropriate instructional manipulation regarding how they should complete the problems. Subjects in the "Demonstration" condition were told to examine the prime and then write down a reason why the prime was consistent with the data. Subjects in the "Fix" condition were instructed to think of a hypothesis that was consistent with the data for a different reason than the prime. They were to list that hypothesis and the reason why it was consistent with the data. Then they were told to list as many hypotheses as possible that were consistent with all of the data. All subjects then completed an example problem so that the experimenter was sure that they understood the instructions. Verbal interaction between the experimenter and the subjects occured during the practice problem to insure that the subjects understood the task. Following this example, subjects were instructed to work on the problems at their own pace.

Results and Discussion

Scoring procedures. The experimenters collected all generated hypotheses for the three problems for all subjects. Each different hypothesis was then rated as being consistent with the MA schema, the LA schema, or some other schema. This procedure eliminated the tendency to bias the results by making a decision about which schema fit a certain hypothesis while looking at a subject's test form.

A comparison of the number of hypotheses generated in the primed conditions with the control conditions is complicated by the fact that those subjects who saw either prime did not have the opportunity to generate that hypothesis, while subjects in the "No Prime" condition had the opportunity. Consequently, subjects' hypothesis lists were adjusted for the problems on which the subject had seen a prime. The adjustment factor was computed by finding the proportion of times that subjects in the corresponding control condition generated a prime. This proportion was added to the data of the primed subjects. A different set of adjustment factors was computed for each of the instructional manipulation conditions because their control groups were not directly comparable. Subsequent analyses were performed on these transformed scores. These analyses are organized according to the experimental questions addressed in the following section. An analysis of variance was performed on the number of hypotheses generated. This number included the adjustment factor described above.

As expected, subjects as a rule generated more hypotheses that were consistent with the MA schema, $F(2,504) = 61.05$, $p < .0001$, and fewer that were consistent with the LA schema. This result occurred for all problems, although the interaction between the type of schema under which a hypothesis was categorized and problems was also significant, $F(4,504) = 20.77$, $p < .0001$. This interaction occurred due to differences in problems, and when examined showed no interesting effects.

The main effect of prime type was not significant. However, there was a significant interaction between the prime administered and the types of hypotheses generated, $F(4,504) = 10.45$, $p < .0001$. Figure 1 shows this

interaction, illustrating the mean numbers of hypotheses generated that were consistent with each type of schema as a function of the prime administered.

Insert Figure 1 about here

Does the presentation of a presumed hypothesis enhance the generation of those hypotheses that are consistent with the presumed schema? The question of interest is the effect of the presumed hypothesis on the frequency of generation of hypotheses consistent with the presumed schema. Figure 1 shows an interesting interaction. If the presumed hypothesis suggests the MA schema, then the frequency of generating MA hypotheses is not significantly greater than the frequency of MA hypotheses for the control subjects. If, on the other hand, the presumed hypothesis suggests the LA schema, then there is considerable increase in the frequency of generating LA hypotheses as compared to the control. The number of LA hypotheses generated almost doubles, and this effect is significant as shown by a planned comparison ($t(504) = 2.92$, $p < .05$). Our initial expectations were that the presumed hypothesis would increase the frequency with which hypotheses are generated irrespective of the accessibility of the schema, but apparently only the generation of hypotheses consistent with the LA schema is enhanced. It may be that the salency of the MA schema was so high that subjects usually accessed this schema without prompting by a presumed hypothesis. In the case of a LA presumed hypothesis where the unprompted accessessability of the schema was low, the presumed hypothesis may have increased the accessibility of hypotheses consistent with the LA schema, giving rise to these results.

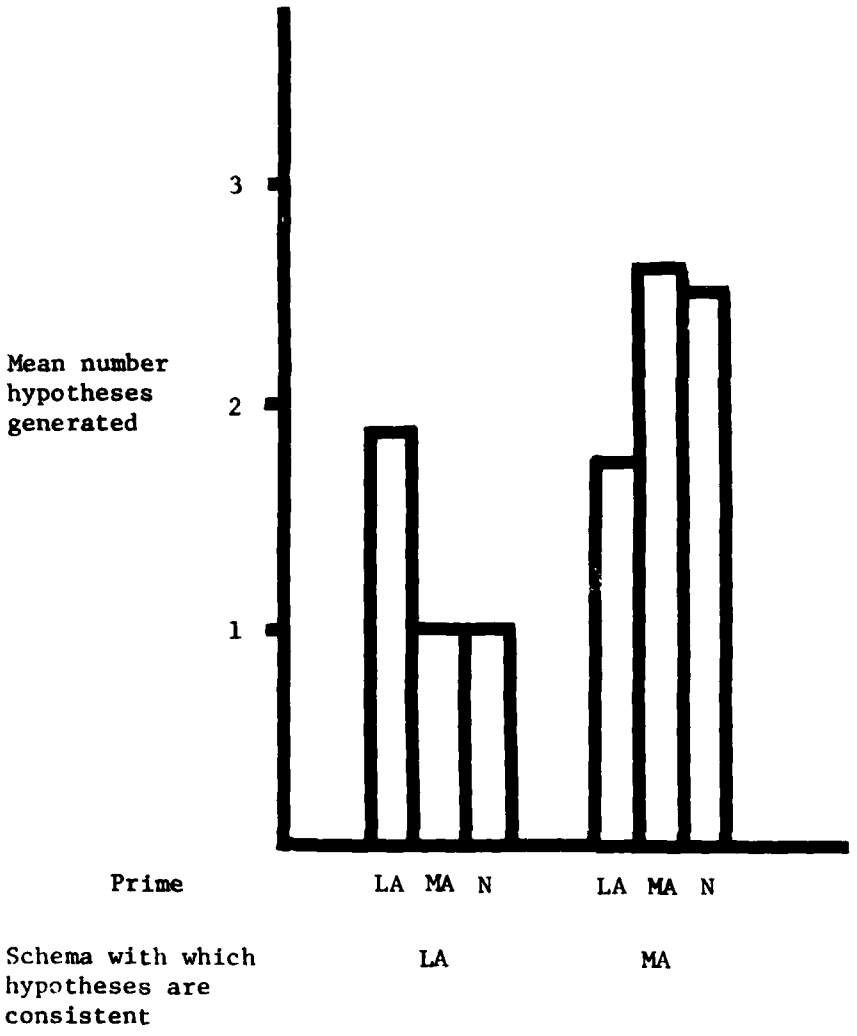


Figure 1. Mean number of hypotheses generated by subjects in "Demonstration" condition as a function of the prime administered and the type of schema with which the hypothesis is consistent. LA represents "less-accessible", MA represents "more accessible, N represents "None".

Does the presentation of a presumed hypotheses suppress the generation of hypotheses that are consistent with other schemata? We predicted that presenting a prime should decrease the probability of generating a hypothesis consistent with all schemata other than the presumed schema. Our results showed that the effect again depended on the type of prime presented. Presenting a MA prime did not decrease the number of hypotheses generated that were consistent with a LA schema. However, presenting a LA prime affected the generation of those hypotheses consistent with the MA schema. An a priori comparison showed that presenting a LA prime caused subjects to generate significantly fewer hypotheses that were consistent with the MA schema than did subjects in the control group ($t(504) = 2.54$, $p < .05$).

These results imply that presenting a MA presumed hypothesis causes subjects to respond as they ordinarily would and employ the corresponding presumed schema as a retrieval cue. Thus the frequency of generating hypotheses that are consistent with the MA schema and the frequency of generating hypotheses consistent with the LA schema are about the same as that of the control condition. However, presenting a LA presumed hypothesis causes the corresponding presumed schema to compete with the MA schema for the role of retrieval cue. After an LA prime, hypotheses are about equally distributed between the two schemata.

Does a manipulation that makes another schema more accessible affect the types of hypotheses that subjects generate? We had predicted that instructing subjects to think of an exemplar hypothesis that was consistent with the problem data for another reason than was the prime should provide them with another retrieval cue. The alternate schema should thus provide an alternate interpretation of the data than the prime. Subjects in the

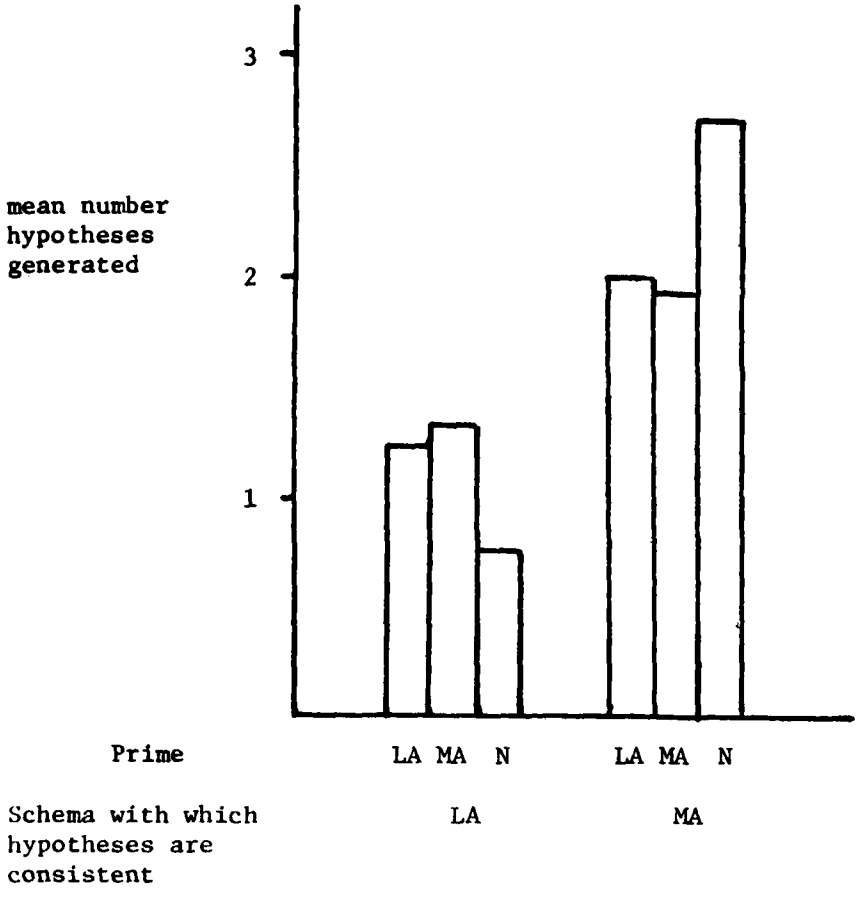


Figure 2. Mean number of hypotheses generated by subjects in "Fix" condition as function of the prime administered and the type of schema with which the hypothesis is consistent. LA represents "less accessible", MA represents "more accessible", N represents "None".

"Fix" condition who saw a prime should generate more varied hypotheses than their counterparts in the "Demonstration" condition who received the same prime.

Subjects in the "Fix" condition were told to generate a hypothesis that was consistent with the data for some reason other than the reason which was true for the presumed hypothesis. Often subjects in this condition generated a hypothesis that was not different from the presumed hypothesis by our standards. This result may have occurred for several reasons. First, the experimenters did not provide the presumed schema; thus subjects could employ their subjective schemata when considering the problems. Subjects may have used a different criterion than the experimenters to determine why the two hypotheses were different. Some subjects may have been unable to think of a schema that was different from the presumed schema.

On only 52.6% of the problems did the Experimenters find that the subjects in the "Fix" employed a different schema than the presumed schema. An analysis of variance was performed on these data. The interaction between Prime, type of hypothesis generated and instructional manipulation was significant ($F(4,376) = 2.40$, $p < .05$). Figure 2 shows the pattern of responses generated by subjects in the "Fix" condition.

Insert Figure 2 about here

Comparing Figure 2 with Figure 1 shows that presenting a presumed hypothesis affected subjects in the "Fix" condition differently than it did subjects in the "Demonstration" condition. Subjects in the "Fix" condition tended to use both schemata when generating hypotheses. Figure

2 shows that presentation of either a LA or MA presumed hypothesis caused subjects to generate more hypotheses that were consistent with the LA schema than did control subjects, although an a priori comparison showed that this difference was not significant. Similarly, the presentation of either a LA or MA presumed hypothesis caused subjects to generate fewer hypotheses that were consistent with the MA schema. Again, this decrease was not significant.

These results suggest that subjects utilize all accessible schemata as retrieval cues. A more salient schema will be a more powerful retrieval cue, but if a less-accessible schema is accessible to a subject, then this schema will be incorporated in subsequent hypothesis generation.

An interesting result that relates to the previous discussion was that the total number of hypotheses generated was approximately the same for subjects in all conditions. The mean number of hypotheses generated was 4.58 (standard deviation = 2.28). This implies that subjects in different experimental conditions changed the types of hypotheses that they generated but did not increase the total number of hypotheses. One might expect that subjects in the "Fix" condition who had access to more than one schema to use as a retrieval cue should generate more hypotheses than subjects in the "Demonstration" condition, but this was not the case. Subjects may have a point at which they arbitrarily choose to stop generating hypotheses, no matter how many hypotheses are accessible to them.

Conclusions. This experiment was designed to answer several questions about how the presence of a presumed hypothesis affects hypothesis generation performance. Recall that a presumed hypothesis is one that may have been suggested to a decision maker by someone who has already examined the problem

and generated his or her own hypotheses. A major goal of the decision maker is to integrate the data of a problem into a meaningful form. The presumed hypothesis should be incorporated into a presumed schema that is used to give meaning to the problem. This schema may be used as a retrieval cue for further hypothesis generation. We asked several questions about this process. Does the presence of a presumed hypothesis enhance the generation of hypotheses consistent with the presumed schema? We found that this depends on the saliency of the presumed schema. If the presumed schema is highly-accessible to subjects, one that they tend to adopt fairly frequently, then subjects generate hypotheses about as they would if no presumed hypothesis were present. However, if the presumed schema is rarely accessible, then subjects generate significantly more hypotheses consistent with that schema than they would if they saw no presumed hypothesis.

Does the presence of a presumed hypothesis suppress the generation of other types of hypotheses? Results suggest that presenting a presumed hypothesis consistent with a less-accessible schema suppresses the generation of hypotheses consistent with a more-accessible schema. However, hypotheses consistent with a less-accessible schema are relatively inaccessible, so presenting a presumed hypothesis consistent with a more-accessible schema does not reduce the frequency of their being generated.

Does a manipulation that makes another type of schema more accessible affect the types of hypotheses that subjects generate? We found that an instructional manipulation that stimulated subjects to consider other types of schemata did affect the frequencies with which they generated different types of hypotheses. It appeared that subjects used both schemata that they considered as retrieval cues.

One way of obtaining a varied list of hypotheses is to present a decision maker with a fairly unusual hypothesis as a possible solution. Another method of obtaining varied hypotheses is to encourage the decision makers to change their schema, or to examine the data from a different perspective. Those subjects who could generate additional schema were the ones who were successful in generating more varied hypotheses.

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